Prospective Evaluation of the Radiologist’s Hand Dose in CT-Guided Interventions

Zusammenfassung

Ziel: Ermittlung der Handdosis des Interventionalisten im Rahmen unterschiedlicher computertomografisch (CT-)gestützter Interventionen und Evaluation von Einflussfaktoren.

Material und Methoden: Bei folgenden CT-gestützten Eingriffen wurde die Handdosis mit einem sofort ablesbaren Dosimeter EDD-30 (Unfors, Schweden) ermittelt: Stanzbiopsien, Drainageeinlagen, periradikuläre Therapie sowie Truncus coeliacus Neurolyse. Alle Interventionen wurden an einem 16-Zeilen-CT (Aquilion 16, Toshiba, Japan) in CT-Fluoroskopie-Technik durchgeführt, wobei die Standard-Parameter 120 kV-Röhrenspannung, 90 mA-Röhrenstrom sowie 4 mm-Schichtdicke waren. Es wurden Tumorgröße, Schwierigkeitsgrad (1–3), Erfahrungsgrad des Interventionalisten, Nadeldurchmesser und die Geräteparameter (mAs, Dosis-Längen-Produkt sowie die Scanzzeit) dokumentiert.

Ergebnisse: In die Auswertung gingen 138 CT-gestützte Interventionen (Lokalisationen: Lunge n = 41, Retroperitoneum n = 53, Leber n = 25 und...
Würbelsäule n=19) mit 3 verschiedenen Prozeduren (Biopsien n=99, Drainagen n=23 und Schmerztherapien n=16) ein. Die zu biopsierenden Läsionen hatten eine Größe von 4–240 mm (Median 23 mm). Die Fluoroskopiedauer pro Intervention lag zwischen 4,6 und 140,2 s (Median 24,2 s). Die mit dem EDD-30 gemessene Handdosis reichte von 0,001–3,02 mSv (Median 0,22 mSv). Die Handdosiswerte für Lungenpunktionen (n=41) bewegten sich auf einem höheren Niveau (Median 0,32 mSv; p=0,01) im Vergleich zu Interventionen an Leber, Retroperitoneum und Wirbelsäule. Neben den physikalischen Einflussgrößen zeigten der Schwierigkeitsgrad (p=0,001) und die summierte Stichtiefe (p=0,004) einen signifikanten Einfluss auf die Handdosis. 

Schlussfolgerung: Bei den evaluierten Eingriffen wurde eine mediane Handexposition von lediglich 0,22 mSv festgestellt, sodass theoretisch über 2000 Interventionen pro Jahr von einer Person durchgeführt werden können, bevor der Handdosis-Grenzwert von 500 mSv erreicht wird.

Introduction

Nowadays, minimally invasive CT-guided interventions play an important role at many institutions and are routinely performed. CT fluoroscopy was first introduced in the clinical routine by Kato and Kado in 1993 [1]. Images can be acquired with real-time control, high geometric precision, and without significant artifacts, resulting in increased accuracy, reduced intervention times, and improved biopsy results [2–6]. However, interventions performed under CT fluoroscopy guidance entail relevant additional radiation exposure for the personnel involved in the intervention. In particular, manipulations performed in the direct beam path of the CT unit can result in significant skin doses for the examiner [4, 7, 8]. CT fluoroscopy-guided interventions are currently a fixture in the clinical routine due to the wide range of possible applications. In the last decades, the interventional possibilities and indications of CT have continued to expand, e. g. to the areas of interstitial brachytherapy and radiofrequency ablation [9–14].

Objective

Due to the increase in CT fluoroscopy-guided interventions and their complexity, it is necessary to conduct a detailed analysis of the radiologist’s hand dose exposure. The hand dose range and the risks for the operator must be determined. This raises the following questions: Is the annual hand dose limit of 500 mSv for persons occupationally exposed to radiation reached? Which influencing factors result in a higher hand dose?

Materials and Methods

Patient Data

In the prospective study for examining the radiologist’s hand dose, 138 CT-guided interventions involving 131 patients were able to be completed between November 2009 and December 2010. The following interventions were included: CT-guided core biopsy, CT-guided drainage, and CT-guided pain therapy (periradicular therapy and neurolysis/block of the celiac plexus). The study was approved by the Ethics Committee of the Medical Faculty of the Otto-von-Guericke University of Magdeburg.

Inclusion and exclusion criteria for the CT-guided interventions

Inclusion criteria

- All interventions had to be performed on a 16-slice multidetector CT unit (Aquilion 16, Toshiba, Japan) using CT fluoroscopy.
- The preliminary diagnostic CT examination had to show a clearly defined target lesion or target region (in the case of periradicular therapy or celiac plexus neurolysis).
- Re-interventions were possible.
- Interventionists were required at least 6 months of experience with CT-guided interventions.

Exclusion criteria

- Complex interventions (e. g. CT-guided brachytherapy or radiofrequency ablation),
- puncture of multiple lesions during the same procedure,
- active participation of multiple interventionists in the puncture procedure,
- misplacement of the EDD-30 sensor or periinterventional shifting of the sensor,
- lack of documentation regarding the needle tip position/drainage system or lack of documentation regarding the contrast agent distribution during interventional pain therapies,
- change of the default slice thickness or tube voltage.

Measurement methods

The hand dose was measured with an immediately readable electronic dosimeter, the EDD-30 (Unfors, Sweden). The detection threshold of the sensor is a dose rate of 10 nGy/s (range: 10 nGy/s – 0.6 mGy/s) [15]. The EDD-30 sensor was attached to the back of the interventionist’s dominant hand. It was positioned between the head of the 2nd and 3rd metacarpal bone (Fig. 1).

Fig. 1 EDD-30 sensor affixed to the back of the right hand combined with bilaterally affixed TLD plates.
Validation of the dose measurement via the thermoluminescence detector (TLD) measurement method

In an initial validation study of the hand dosimeter, a simultaneous measurement with TLD plates (Hp 0.07) involving 31 patients was performed. A plate was adhered directly to the right and to the left of the EDD-30 sensor (Fig. 1).

Technical parameters

All interventions were performed on a 16-slice CT unit (Aquilion 16, Toshiba, Japan). The default technical parameters for CT fluoroscopy were 120 kV, 90 mA, a 4 mm slice thickness, and a tube rotation time of 0.5 s. In the case of six obese patients (BMI > 30 kg/m²), the tube current intensity had to be increased (to 200 mA for five patients and 300 mA for one patient) due to a decrease in image quality. A combination of discontinuous/intermittent and continuous fluoroscopy was used. Radiation protection gloves were not worn. A standard needle holder (14 cm) was used for 13 retroperitoneal punctures. The following radiation protection measures for the interventionalists were taken: Radiation protection apron with thyroid protection (0.35 mm Pb equivalent), radiation protection glasses, and a lead blanket for the patient.

Recorded parameters

The following variables were documented: Tumor size (anterior–posterior size, width and craniocaudal diameter), location, name of the interventionalist, level of experience, degree of difficulty (1–3), body-mass index of the patient, and scan parameters, such as tube current time product (mAs), dose-length product (DLP), and fluoroscopy time. Moreover, the distance between the skin surface and the needle tip (penetration depth) was measured. In the case of six obese patients (BMI > 30 kg/m²), the tube current intensity had to be increased (to 200 mA for five patients and 300 mA for one patient) due to a decrease in image quality. A combination of discontinuous/intermittent and continuous fluoroscopy was used. Radiation protection gloves were not worn. A standard needle holder (14 cm) was used for 13 retroperitoneal punctures. The following radiation protection measures for the interventionalists were taken: Radiation protection apron with thyroid protection (0.35 mm Pb equivalent), radiation protection glasses, and a lead blanket for the patient.

Classification of the different interventionalists

The eleven interventionalists were classified according to their levels of experience (two different levels of experience):

1. low level of experience (<5 years of experience with CT fluoroscopy interventions),
2. high level of experience (>5 years of experience with CT fluoroscopy interventions).

Classification according to degree of difficulty

The interventions were categorized according to three degrees of difficulty with the lesion size and the position in relation to other risk structures being taken into consideration. Two radiologists retrospectively and independently categorized the interventions (based on the acquired CT images) according to three degrees of difficulty. In the case of differences in the degree of difficulty (due to varying reader evaluation), the higher degree of difficulty was used. The classification according to degree of difficulty on a scale of 1–3 was based on the following criteria:

1. lesion >2 cm and risk structures at a distance of >3 cm in relation to the lesion and the path of the puncture channel,
2. lesion <2 cm and adjacent risk structures >2 cm away, angled path of puncture; lung puncture with a distance of >2 cm from the pleura,
3. lesion <1 cm in a space orientation and risk structures directly adjacent to or along the puncture channel.

Despite the size of the target area: 5 × 5 × 5 mm³, periradicular therapy was classified as easy (degree of difficulty 1).

Data Analysis and Statistics

A descriptive data analysis was first performed. Since many of the analyzed variables have an asymmetrical distribution, the median and the extreme values were always provided in addition to the mean and standard deviation. Group differences and correlations between the variables were also examined with nonparametric tests. The following statistical methods were used for this purpose: The group differences (different procedures and locations) of the measured hand dose values were analyzed with a Kruskal-Wallis test. To evaluate the influencing factors with respect to the measured hand dose values, a multivariate analysis and a Spearman–Rho rank correlation coefficient test were performed. Univariate variance analyses were used for the simultaneous analysis of degree of difficulty and level of experience with respect to hand dose and fluoroscopy time. The classification of the degree of difficulty by the two readers was checked with a Cohen’s Kappa analysis. A significance level of α = 0.05 (two-sided) was used for all tests.

Results

The distribution of the 138 CT-guided interventions completed between November 2009 and December 2010 is shown in Fig. 2. The median body-mass index of the included patients was 24.7 kg/m² (standard deviation: 7.5 kg/m²).

Comparison of the reference TLD measurements and the EDD-30 measurements

The mean deviation was –7.33 % (95 % tolerance interval for the individual measured value pairs: 0.678–1.175). The hand dose measured with the EDD-30 was slightly lower than the doses measured with the TLD.

Dose measurements

The measured hand dose values ranged from 0.001–3.02 mSv and the median was 0.22 mSv (mean: 0.315 mSv, standard deviation: 0.391 mSv). The hand dose median for lung interventions (0.32 mSv; n = 41) was slightly higher than that of interventions in the region of the liver (0.248 mSv; n = 25) and in the retroperitoneum (0.17 mSv; n = 53) and the spine (0.014 mSv; n = 19); (p = 0.01).

The maximum single hand dose value (3.02 mSv) was reached during a retroperitoneal puncture of the pancreas. Without taking the anatomic location into account, the median hand dose value was 0.23 mSv (0.005–0.34 mSv) in the biopsy group (n = 99), 0.26 mSv (0.027–0.979 mSv) in the drainage group (n = 23), and 0.01 mSv (0.001–0.077 mSv) in the pain therapy group (n = 16); (p = 0.011) (Fig. 3).

The median fluoroscopy time was 24.2 s (mean: 30.7 s; 4.6–140.2 s; standard deviation: 23.4 s).
The longest median fluoroscopy time of 32.5 s was reached during liver puncture followed by interventions involving the lungs (25.8 s), retroperitoneum (23.5 s), and spine (17.9 s). The median scan time was 25.5 s (5.6 – 140.2 s) in the biopsy group, 20.2 s (4.6 – 66.4 s) in the drainage group, and 17.7 s (8.8 – 48.3 s) in the pain therapy group; (p = 0.015) (Fig. 4).

The mean dose-length product for fluoroscopy was 123.19 mGy×cm (standard deviation: 104.73 mGy×cm).

Classification according to level of experience and degree of difficulty
The experienced interventionalists (level of experience 2) conducted a total of 97 interventions (64 core biopsies, 18 drainages, 11 periradicular therapies, and 4 celiac plexus blocks). In contrast, the inexperienced interventionalists (level of experience 1) only performed 42 interventions (36 core biopsies, 5 drainages, and 1 celiac plexus block). Fig. 5 shows the classification of the interventions according to the three degrees of difficulty and the level of experience. The interrater reliability for the classification according to degree of difficulty (measure of the agreement between the two radiologists) or the Cohen’s kappa value was 0.739 and is therefore to be evaluated as “considerable agreement” [16].

Statistical evaluation of the influencing factors
We used the Spearman-Rho rank order correlation test for the three target variables, hand dose, fluoroscopy time, and dose-length product (DLP), to analyze the influencing factors. The following table shows the correlations of important factors with the hand dose exposure (mSv), fluoroscopy time (s), and dose-length product (mGy×cm).

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Hand Dose Exposure (mSv)</th>
<th>Fluoroscopy Time (s)</th>
<th>Dose-Length Product (mGy×cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biopsy</td>
<td>35</td>
<td>3</td>
<td>101.78</td>
</tr>
<tr>
<td>Drainage</td>
<td>75</td>
<td>4</td>
<td>119.24</td>
</tr>
<tr>
<td>Pain Therapy</td>
<td>99</td>
<td>6</td>
<td>133.52</td>
</tr>
</tbody>
</table>
tant variables and the associated significance (Table 1). The physical relationships of fluoroscopy time, dose-length product, and the mAs product were confirmed with correspondingly strong correlations ($r \geq 0.9$). However, the fluoroscopy time and the tube current time product only showed a weak linear relationship to the interventionalist’s hand dose ($r = 0.411$ and $r = 0.418$; in each case $p = 0.01$). A high degree of difficulty resulted in a longer fluoroscopy time, a greater dose-length product, and a higher hand dose for the interventionalist ($r \leq 0.344$; in each case $p = 0.001$). The more often a lesion was punctured, the greater the effect on the hand dose and the fluoroscopy time ($p = 0.023$ and $p = 0.029$). The needle diameter (needle thickness) showed a significant negative relationship in regard to the hand dose ($r = -0.25$; $p = 0.003$). This can be explained by the fact that thinner biopsy needles were primarily used for lung interventions which resulted in higher hand doses. The number of puncture attempts and the summed puncture depth showed significant but only weak correlations to the fluoroscopy time ($p = 0.029$; $p = 0.001$) and hand dose ($p = 0.023$; $p = 0.004$) (Table 1). In the Spearman-Rho analysis no significant correlation between the level of experience and the hand dose could be shown. A significant correlation also couldn’t be shown via two-factor univariate variance analysis of the level of experience and the degree of difficulty ($p = 0.946$). In the case of an average degree of difficulty (2), the inexperienced interventionalists had a lower average hand dose value (0.313 mSv) compared to the experienced interventionalists (0.345 mSv); $p = 0.45$, while the opposite was true in the case of easy interventions (degree of difficulty 1) (0.213 vs. 0.165 mSv; $p = 0.82$). However, the level of experience did have a significant influence with respect to the fluoroscopy time ($p = 0.03$). The body-mass index resulted in a higher tube current setting in six cases but did not have a significant effect on the hand dose in the analysis ($p = 0.308$). Multivariate analysis was only able to confirm the tube current time product ($p = 0.001$), the degree of difficulty ($p = 0.004$), and the summed puncture depth ($p = 0.045$) as significant influencing factors on the hand dose. In the biopsy group, the craniocaudal lesion

<table>
<thead>
<tr>
<th>variable</th>
<th>DLP correlation coefficient</th>
<th>DLP significance (2-sided)</th>
<th>Fluoroscopy time correlation coefficient</th>
<th>Fluoroscopy time significance (2-sided)</th>
<th>Hand dose correlation coefficient</th>
<th>Hand dose significance (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoroscopy time</td>
<td>0.923&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.001</td>
<td>1.000</td>
<td>0.411&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mAs</td>
<td>0.905&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.001</td>
<td>0.943&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.418&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degree of difficulty</td>
<td>0.329&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.001</td>
<td>0.285&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.344&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of experience</td>
<td></td>
<td></td>
<td>-0.110</td>
<td>-0.148</td>
<td>0.132</td>
<td>0.001</td>
</tr>
<tr>
<td>Needle diameter</td>
<td></td>
<td></td>
<td>-0.075</td>
<td>-0.014</td>
<td>-0.250&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.003</td>
</tr>
<tr>
<td>Number of punctures</td>
<td></td>
<td></td>
<td>0.397</td>
<td>0.873</td>
<td>0.194&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.023</td>
</tr>
<tr>
<td>Summed puncture depth</td>
<td></td>
<td></td>
<td>0.379</td>
<td>0.342&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.247&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Significant results are in **bold**.

<sup>1</sup> The correlation is significant (two-sided) at $\alpha = 0.01$.
<sup>2</sup> The correlation is significant (two-sided) at $\alpha = 0.05$.  

![Fig. 4](image-url) Different procedures and their fluoroscopy times (illustrated median values.)

**Table 1** Spearman-Rho-Analysis regarding influence factors.
the back of the hand is usually turned away from the gantry
0.57 mSv) and comparable to our measurements. Moreover,
that smaller tumor diameters resulted in a longer fluorosco-
ype time and a higher hand dose.

**Evaluation of the hand dose with respect to the use of a**
**needle holder**
The Mann-Whitney test was used to evaluate the reduction in
radiation exposure due to the use of a needle holder with
a coaxial needle in retroperitoneum interventions. This
showed a lower median hand dose value of 0.08 mSv
(n = 13) compared to a value of 0.23 mSv (n = 40) without
the use of a needle holder. The significance level was almost
met with p = 0.052.

**Discussion**

**Hand dose measurements of the TLD versus the EDD-30**
A maximum dose rate of 0.6 mGy/s can be recorded with the
immediately readable EDD-30 dosimeter, which does not
seem particularly high compared to the dose values in
the direct beam path (up to 10.4 mGy/s) [15, 17]. For this rea-
son, the 31 simultaneous comparison measurements using
TLD plates were performed. However, identical measured
values could not be expected due to the test setup since the
plates were not in the exact same position as the EDD-30
sensor (Fig. 1). The slightly lower measured values can be
explained by a directional dependence of the EDD-30 sen-
sor [15]. Other electronic dosimeter models had satisfactory
measurement accuracy in clinical use compared to the TLD
but the applied dose can be underestimated in the direct
beam path [18].

**Hand dose values**
The hand dose median was 0.22 mSv regardless of the pro-
cedure and location. This means that it would take over
2000 CT interventions to reach the annual limit value. In
the study by Buls et al. (2003), the median hand dose for
the right hand was 0.76 mSv which is significantly higher
than our measured values [19]. However, our values were
significantly higher than those of Stoeckelhuber et al.
(2003) (0.0295 mSv per case) [20]. An explanation for these
lower hand dose values is the use of radiation protection
gloves and long needle holders. The biopsy needles of our
interventionalists were controlled by grasping a side wing
of the biopsy system and an angled puncture technique
with a “floating CT table” was often used, thus preventing
manipulations in the direct beam path. In contrast to these
results, the comprehensive dose measurements involving
interventionalists’ fingers by Pereira et al. (2011) yielded
very different results. Despite the additional use of radiation
protection gloves, extremely high dose values (up to 36.29
mSv) were measured. It must be mentioned that the TLD
measurements were taken at eleven measurement points
on the hand (proximal and distal on every finger and on
the wrist). Therefore, the proximity to the direct beam path
differed greatly from our measurement method [21]. The
hand dose values measured at the wrist were lower (0.07 –
0.57 mSv) and comparable to our measurements. Moreover,
the back of the hand is usually turned away from the gantry

in our measurement, which also explains the lower hand
dose values. The substantial variation of the measured
hand dose values is consequently dependent on manipula-
tions in the immediate vicinity of the direct beam path and
the use of continuous fluoroscopy. In the direct beam path a
dose rate of up to 10.4 mGy/s (120 kV, 90 mA) can be expec-
ted. This value drops to 27 µGy/s (120 kV, 50 mA) at a dis-
tance of 10 cm [17]. Moreover, there is no clearly defined
fixed point for hand dose measurements so that there can
be significant deviations in the measurements of other
authors. More complex interventions, such as CT-guided bra-
ch therapy or radiofrequency ablation, were not included
in this study. Higher hand dose values would be expected in
these cases.

**Influencing factors**
In addition to the physical influences to be expected
(fluoroscopy time, tube current time product, needle size,
lesion size, and summed puncture depth), the degree of dif-
ficulty of the intervention could also have a major effect on
the hand dose. For the procedures with an easy or average
degree of difficulty (biopsy, drainage, and pain therapy),
there was surprisingly no significant difference in hand
dose between the inexperienced and experience interven-
tionalists. A possible explanation for this could be the great-
er respect of the inexperienced interventionalists for the
direct beam path or their avoidance of continuous fluoro-
scopy. Furthermore, level of experience 2 as defined by us
(> 5 years of experience) could be too high. However, the in-
experienced interventionalists needed on average approxi-
mately 40% more scan time even though they only per-
formed one difficult intervention (degree of difficulty 3)
(Fig. 5).

**Biological effect of radiation exposure on the hand**
Careless use of X-rays already had significant consequences
at the beginning of the X-ray era. Accordingly, radioderma-
titis of hands exposed to radiation (so-called “Roentgen
hand”) was documented for the first time in 1896 [22, 23].
Deterministic radiation effects are not expected in the case
of the measured hand doses. Since there is no limit value for
the stochastic radiation effect, every X-ray quantum is in
principle carcinogenic so that the risk estimate of a chronic
suberythemal hand dose is difficult to determine [24, 25].
From the Life Span Study of atomic bomb survivors, an in-
crease in the incidence of basal cell carcinoma due to the
additional radiation exposure was able to be confirmed
[26, 27]. The hand dose values measured in the present
study yielded the following risk estimates (two alternative
calculations) on the basis of the ICRP 103 publication [28]
and according to Preston et al. [27]: Calculation of the cu-
mulative total hand dose (30 years professional experi-
ence): 0.22 mSv (median hand dose per intervention) × 3
(interventions/day) × 250 (work days) × 30 (years) = 4.95 Sv.
The nominal risk coefficient for the skin is 670 cases per
10,000 persons per Sv. This results in 4.95 Sv × 0.067 per-
sons/Sv. Consequently, the risk of incidence of “non-mela-
nocytic” skin cancer according to these calculations is
33.1% (with a very low mortality rate of 0.07% and a case
fatality rate of 0.002 [28]). An alternative calculation accord-
ing to the relative risk model on the basis of the Life Span
Study analysis (based on Table 27 from Preston et al. 2007
shows the following: The excess relative risk is 0.17 per Sv resulting in 4.95 Sv × 0.17/Sv = 0.84 as an excess relative risk. This value would have to be multiplied by the lifetime risk of developing basal cell carcinoma (incidence approximately 100 per 100,000 people × 80 years × 0.84 = 7 % [29]). This would therefore result in a lower additional risk compared to the first calculation (7 %; mortality rate: 0.014 %, case fatality rate: 0.004 [27–30]). Despite these calculations of the risk of incidence, the annual hand dose limit of 500 mSv for persons occupationally exposed to radiation was not reduced by the German Commission on Radiological Protection or in the amendment of the X-Ray Ordinance 2011. In the statement of the German Commission on Radiological Protection regarding the topic of “dose limits for occupational skin exposure to ionizing radiation”, the above calculations are dismissed and surface personal dose measurement is greatly overestimated [31, 32].

With the following additional radiation protection tools/measures, the hand dose can be greatly minimized: Use of a needle holder, fluoroscopy with low tube current intensity (possibly with incremental adjustment, start thorax: 10 mA; abdomen: 30 mA) or lower tube voltage (≤ 120 kV), low collimation (≤ 4 mm to lower the scattered radiation), restrictive use of continuous fluoroscopy, “angular beam modulation”, and, if possible, use of radiation protection gloves [17, 20, 33, 35]. However, radiation protection gloves can give a false sense of security thus resulting in higher hand dose values [35].

**Conclusion**

An interventionalist would have to perform over 2000 CT interventions (at a hand dose median of 0.22 mSv) to reach the annual hand dose limit value of 500 mSv. In addition to the physical parameters, the summed puncture depth and the degree of difficulty have a significant effect on the hand dose. The estimates regarding the additional radiation risk posed by CT fluoroscopy interventions on the radiologist’s hand dose only allow ambiguous conclusions. Additional radiation protection measures or tools should therefore be used.

**References**

15 EDD-30, Unfors Product brochure. 2010